First Optical Packet Switching Demonstration with Sixteen-Channel InP Monolithically Integrated Wavelength Selector Module

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Abstract: The first demonstration of optical packet switching with an InP monolithic 16-channel wavelength selector module is reported. Switching time below 5 ns, wide input power dynamic range of 15 dB, average polarisation dependent loss below 2 dB and error free transmission are demonstrated.

Introduction

Fast optical switching technology compatible with the constraints of packet applications is one of the emerging technologies able to cope with the intensive growth of data traffic generated by Internet-borne services. It offers the required capacity as well as high flexibility. To realize optical packet switching systems, space and wavelength switching with time responses in the *ns* range are mandatory functions that can be achieved by devices based on Semiconductor Optical Amplifiers (SOA's) used as optical gates /1/. WDM channel selectors are such key components that achieve fast switching of wide band elements (SOA's) associated to fixed (de)multiplexers, providing inherent stability. They have already been reported with both hybrid integration /2/ and monolithic integration /3/. Furthermore, we recently reported flip-chip mounting of a sixteen-channel InP monolithic device on an AlN submount /4/. In this paper, we present a sixteen-channel InP monolithically integrated wavelength selector module and demonstrate for the first time to our knowledge that this device is well adapted to a large range of optical packet switching applications (fast wavelength selection / suppression) for metropolitan and backbone networks.

Wavelength selector module

Our device integrates passive sections (phasars) consisting of a deeply etched structure and active sections (SOA's) made of a separate confinement heterostructure with a low tensile-strained bulk active layer. The layers of the passive sections and the top layers of the SOA's were grown using metal organic vapor phase epitaxy while the layers of the active structure were grown using gas-source molecular beam epitaxy. Low propagation loss in the passive sections (~3 dB/cm), as well as low and reproducible coupling loss and low reflectivity at the transitions with the active ones are ensured by a specific integration scheme. This process combines growth of undoped cladding layers in the passive sections with patterning of all stripes in a single lithographic step, leading to self-aligned active and passive sections /5/. The butt-coupling technique of two phased-array wavelength (de)multiplexers and sixteen SOA's achieves high performance : zero-loss operation at low driving current, low polarisation sensitivity, low crosstalk and compactness.

The wavelength spacing of our 16-channel wavelength selector is 200 GHz (1.6 nm) with a free spectral range of 37 nm around 1.55 µm. It consists of two phased-array wavelength demultiplexers, with 80 waveguides in the gratings, and 16 SOA's each 370 µm long. The minimum radius of curvature of the bent waveguides was 100 µm whereas the pitch of the SOA's was 150 µm. Figure 1 shows the chip after cleaving, its total size being only 4.2 mm × 4.6 mm. In order to simplify packaging and ensure fast switching operation, the chip was flip-chip mounted on a Silicon submount comprising a network of coplanar lines connected to an array of AuSn bumps to which the electrodes of the SOA's were soldered.

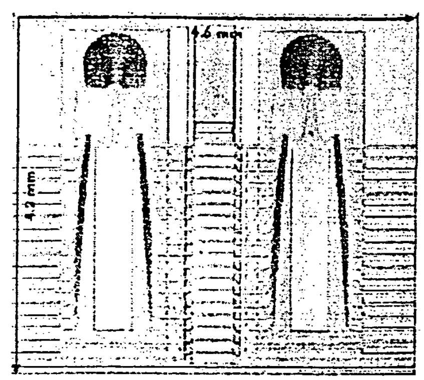

Figure 1: 16-channel wavelength selector chip

The polarisation dependent loss (PDL) of this device is quite low at 1.8 ± 1 dB. Crosstalk is below -40 dB while the 3 dB bandwidth is about 85 GHz.

Transmission experiment

The wavelength selector module has been placed on a 160 mm x 234 mm testing board (Figure 2) including temperature control and 16 fast switching drivers allowing to switch from 0 up to 130 mA. The currents were chosen on each gate (around 90 mA) in order to have the same gain for all the channels.

System experiments were conducted at 10Gbit/s with an NRZ signal and 2^{15}-1-long PRBS. The sensitivity at 10^{-9} BER in back-to-back was -14.3 dBm. Figure 3 shows for a typical example (SOA 2) the sensitivity versus the input optical power for the states of polarisation yielding the lowest and the highest optical powers.

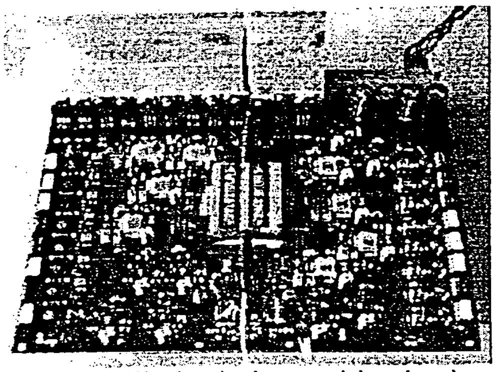

Figure 2: Wavelength selector module on board

The degradation for low optical powers is due to signal-to-noise ratio degradation. The degradation for high optical powers is due to SOA saturation. However, the power range is around 15 dB, giving a high tolerance to optical power fluctuations. We have checked that the crosstalk level is sufficiently low to avoid any penalty due to all other 15 channels.

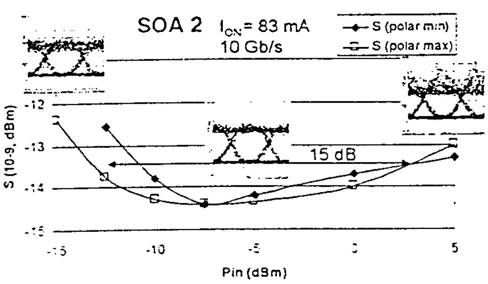

Figure 3: Sensitivity vs. P_{in} for channel 2

Packet switching experiment

We have then considered 1.6 µs-long optical packets separated by 32 ns guard bands. The experiment consists in selecting one packet out of two.

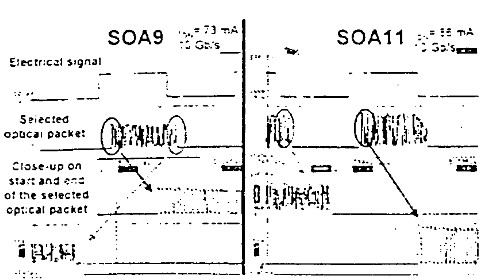

Figure 4: Packet switching with SOA 9 and 11

The input optical power was set at -3 dBm. Figure 4 shows typical selected optical packets. The start and the end of the packet are not corrupted by the switching. In order to check this, we have measured the power penalty versus the moment of switching during the guard band (0 corresponds to the middle of the guard band).

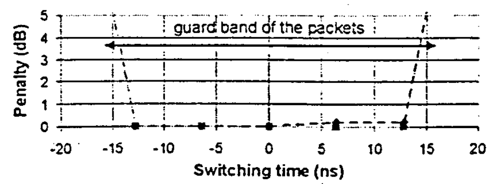

Figure 5: Guarband tuning

As can be shown in Figure 5 for two typical gates, the switching window is above 25 ns out of 32 ns of the guard band, showing that the switching to ON and OFF occurs perfectly with less than 7 ns. Direct measurement of the switching times shows that the SOA's are switched within less than 5 ns.

Conclusion

Hence, we have shown for the first time the optical packet selection through a monolithic wavelength selector module on a board with 16 drivers. The switching time is less than 5 ns yielding high tolerance towards the switching moment within 32 ns guard band and the optical power range is around 15 dB for all the gates yielding a high tolerance to packet by packet power fluctuations. We thus believe that the wavelength selector is a very promising solution for future optical packet networks.

Acknowledgements

The authors would like to thank their colleagues R. Mestric, F. Pommereau, A. Pons, J.-C. Jacquinot, D. Chiaroni and the optics pilotline in Stuttgart for their valuable contribution to this work. This work was financially supported by the French RNRT (Réseau National de Recherche en Télécommunications) in the framework of the FLORA project and the authors also thank their partners M. Havasi (Egide), C. Moussant, C. Aupetit-Berthelemot, J.-M. Dumas (GESTE/ENSIL), C. Saboureau and D. Baillargeat (IRCOM).

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